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Lessons learned for designers and policy makers from the IHSMAG project

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CONTENT

1. Introduction

Since the 2000s, we have witnessed a growing interest in developing the "smart grid". No consensus about the exact definition of the smart grid exists, but it is often associated with an increasingly dynamic electricity system that involves a growing number of actors and with existing actors taking on new or multiple roles (e.g. consumers becoming "prosumers", i.e. both electricity producers and consumers). A key role is often assigned to the integration of new information and communication technologies (ICT) as the basis for a two-way flow of information between electricity consumers, electricity producers and network/system operators in order to enable new smart grid services, e.g. continuous feedback to consumers about their electricity consumption. (Brown & Zhou, 2013; Coll-Mayor et al., 2007; Wissner, 2011)

A number of current issues and developments are often identified as important "drivers" behind the smart grid. The most prevalent are: The need to integrate increasing amounts of renewable electricity generation (as part of climate change mitigation and increased energy sovereignty); ensure the further liberalisation of the electricity market; avoid grid capacity challenges from future increases in electricity consumption (e.g. due to more electric vehicles or increasing micro generation from local PVs and wind turbines) and handle already existing peak-hour capacity problems; make the network management and payment (invoicing) more cost-effective; and, in some countries, reduce problems with electricity theft. (Brown & Zhou, 2013; Geelen et al., 2013)

In the project *Integrating Households in the Smart Grid* (IHSMAG), we have not decided on one specific definition of the smart grid. Rather, our approach has been relatively open as we understand the smart grid as basically characterised by:

1. An increased integration of new ICTs (including an Advanced Metering Infrastructure, AMI) that enables new ways of communicating between different actors.
2. The integration of new actors in the electricity system as well as the assignment of new roles to existing actors (e.g. households as both consumers and producers of electricity).

Obviously, it is necessary to distinguish between the visions about the future smart grid (i.e. *how we talk about the smart grid?*) and the actual changes taking place (i.e. *how the grid is actually changing?*). As seen before in the history of technology, we will most likely witness substantial differences between the original visions and the actual realization of the smart grid over the coming years. For instance, just a few years ago, much attention was on electric vehicles as a way of storing surplus electricity generation for later redelivery to the grid (*vehicle-to-grid*), but the interest has faded somewhat within recent years (probably reflecting the slow uptake of electric vehicles in most countries). Similarly, visions amongst policy makers in the early 2000s tended to highlight that providing electricity consumers with feedback on their current consumption would be the cornerstone of the smart grid, and the means to reach most goals. As technologies have developed, experience has been gained and the visions of implicated actors have changed (Skjølsvold 2014; Ballo 2015). Thus, the focus and interests of the smart grid debate is shifting gradually over time.

While there has been much discussion about the smart grid and its role for households for about ten years, the actual achievements still seem limited. Advanced Metering Infrastructures (AMI), often just termed *smart meters*, are widely diffused in many countries (partly due to regulation and mandatory roll-out), but most of the other elements of the smart grid *vision* are still in the development stage. Many resources are invested by the public and commercial sector in R&D and demonstration projects all over Europe (and in other parts of the world). However, it seems to be a challenge to agree on a common understanding of what “smart” grids means, to get the solutions implemented and working in “real life”, and on market conditions.

There might be several reasons why it is so challenging to transform the original visions of smart grids into workable solutions. Likely, one of the reasons is that the smart grid debate and development in the early years was surrounded by some degree of “hype” that resulted in rather ambitious, and sometimes over-optimistic, visions of the future smart grid, perhaps especially regarding the role of active end users (Throndsen 2016. Also, the field is permeated by a wide range of actors with often differing understandings of what the smart grid should be and with different vested interests. In line with this, Hargreaves et al. (2015) has pointed out that the smart grid – in idea and materiality – is a nuanced fabric formed by interests from a range of different stakeholders. Thus, attempts to “steer the future smart grid are not centralized but formed by multiple distributed practices and actions across public, private, research and civil society sectors” (ibid: 104). This finding has been substantiated by the studies conducted in the IHSMAG project (see, e.g. Skjølsvold & Ryghaug, 2015).

We might now be entering a new phase in the smart grid development, where we will witness a re-evaluation and re-adjustment of the original visions based on experiences from the early years’ smart grid pilots and demonstrations. This report, based on the experiences from a number of demonstration projects in Norway, Spain and Denmark, will be a contribution to this.

In relation to private consumers’ and households’ use of smart grid solutions, which is the focus of the IHSMAG project, another reason for the slow progress is probably related to the fact that much smart grid research, design, development and policy making has been based on a rather narrow understanding of the users of smart grid technologies as consumers. The focus has primarily been on technical and financial considerations and less on broadening our understanding of users and their contextually bound practises (Geelen et al., 2013; Hargreaves et al., 2015; Skjølsvold & Lindkvist 2015). Research and development has typically been based on an understanding of users as consumers, as “rational” individuals that primarily react to economic incentives and concerns about self-interest and utility (Verbong et al., 2013; Strengers, 2013; Hargreaves et al., 2010). In this way, the smart grid field does not differ much from the general approach within consumer-oriented, environmental policies and campaigns (Shove 2010; Shove & Walker 2014) that has tended to view users essentially as a “homo economicus”; as consumers that restlessly seek out new opportunities for maximising personal economic gain. This conceptualisation has also been coined “Resource Man” by Strengers (2013), who has pointed out that this “efficient and well-informed micro-resource manager who exercises control and choice over his consumption and energy options” is a quite misleading understanding (ibid.: 34-35). Solutions based on this understanding tend to over-emphasise the role of information and economic incentives as main vehicles to get people involved and change behaviour. While this may be quite relevant for a minority of users, their lion’s share will not easily be incentivised with such an approach.

In line with this, a review of smart grid projects in Europe (Gangale et al., 2013) shows that smart grid projects typically use information as the primary means to change consumers interest, values and knowledge in order to involve them, while only a few employ more comprehensive approaches such as social marketing or emphasis how to best engage users. Also, the review found that the two most widespread “motivational factors” employed to engage consumers was the reduction of, or control over, the electricity bill (a financial incentive) and environmental concerns (a “green values” incentive). The former refers directly to the Resource Man understanding of the consumer, whereas the second relates to the prevalent understanding of smart grids as part of the decarbonisation strategy of the energy system and, thus, addresses a more general concern for the environment. Verbong et al. (2013: 124) conclude:

> “Although users have become more central in smart grids projects, the focus in the smart grids community is, maybe not surprising, still mainly on technological issues and economic incentives. From this perspective users are often regarded as a potential barrier to smart grids deployment and financial incentives the best instrument to persuade or seduce the users.”

In spite of this, there seems to be a growing recognition of the limitations of such approaches, as well as the need to develop new conceptualisations of users and how to involve them in the future smart grid (Gangale et al., 2013; Hargreaves et al., 2015; Skjølsvold et al. 2015). In other words, an approach that is based on a comprehensive understanding of consumers as users engaged in electricity-consuming everyday practices instead of users being reduced to (self-interest driven) “barriers” in smart grid development. The findings from the IHSMAG project, presented in this report, is a contribution to this crucial change of perspectives.

Another critique of the smart grid development is that the focus is often on *specific* (technical) solutions “rather than the system as a whole” (Geelen et al., 2013: 158). Thus, “product and service development, and as a consequence the related research, has typically focused on empowering end-users with technical solutions and financial incentives.” (Ibid.) According to this critique, there is a need to widen the scope and seek out design solutions that integrate all levels and aspects of the smart grid; i.e. technological solutions that work together with everyday practices of single households and at the same time are aligned with the development of the electricity system, policies and regulations.

The aim of the IHSMAG project has been to contribute with knowledge on how to develop comprehensive designs of smart grid solutions for households. On the basis of experiences and results from a number of demonstration projects in Norway, Denmark and the Basque Country (Spain), IHSMAG has explored how the success of household smart grid solutions depends on household technologies, everyday practices of the household members as well as the overall electricity system and regulatory environment. In this way, our aim has been to provide knowledge and recommendations on how to develop integrative smart grid solutions that take the technical, system-related and social context of households into account.

The IHSMAG project includes three main work packages, each of them focusing on one specific aspect of household smart grid technologies:

- The everyday life of households (this work package was conducted by Danish Building Research Institute, Aalborg University)
- The regulatory and system context of the electricity system (conducted by Norwegian University of Science and Technology)
- The development of new technical solutions in households (conducted by ZIV Metering Solutions / Tecnalia, Spain).

Each of these work packages has resulted in a number of empirical studies with findings and practical lessons about how to improve the design of smart grid solutions for households (reported in separate papers and work package reports; see list of project publications in Chapter 5).

In this report, the outcome of the three main work packages is synthesised in order to develop a number of key lessons from the IHSMAG project regarding *design criteria and policy recommendations* on how to develop *comprehensive and integrative smart grid solutions* that take the technical, system-related and social and everyday life context of households into account. Or, in other words: How to create smart grid solutions for households that work in practice?

The report is organised into two main sections. The first main section (Chapter 2) focuses on design criteria and recommendations for *smart grid designers* (i.e. persons involved in the specific designing of technical solutions related to households). The second main section (Chapter 3) focuses on recommendations for *policy makers, planners and others* involved in defining the conditions for the smart grid development or actually organising the design and development processes, like national energy agencies, politicians, planners within TSOs, DSOs etc. It is obvious that it is in many cases difficult to make a clear distinction between these two groups. However, we find it useful to make this distinction as a way of organising the outcomes of our project.

The IHSMAG project

The “Integrating Households in the Smart Grid” (IHSMAG) project contributed with knowledge on how to develop comprehensive designs of smart grid solutions that involve households in the smart grid. On the basis of experiences and results from a number of demonstration projects in Norway, Denmark and the Basque Country (Spain), the project explored how household smart grid solutions depend on household technologies, everyday practices and the overall electricity system and regulatory rules.

The project began in January 2012 and finished in May 2016 and was supported by the Second ERA-Net Smart Grid Joint Call.

Find more information about the project and its results at: www.ihsmag.eu

2. Recommendations for designers

This section focuses on recommendations and design criteria for the specific design of smart grids solutions for households. These criteria are therefore particularly relevant for people directly involved in development of technical solutions and the set-up of new demonstration projects, etc.

The guiding questions for identifying and developing the following recommendations have been:

- What kind of (technical) solutions work in practice? How do they work?
- What kind of (technical) solutions does not seem to work in practice?
- How can integrated and comprehensive design processes be supported? For instance: What kind of actors and expertise should be involved in the design process? How to involve the users in the design process?
- What kind of organizational processes work best for the development of the smart grid solution?
- What type of regulation may assist the development of the smart grid?

Below, we will present the main recommendations for what should be considered important design criteria based on the results from the IHSMAG project. We begin with the more general observations about what is important to keep in mind when designing smart grid solutions for households and end with a number of specific recommendations. In the following presentation, we will also refer to key findings from other studies, when relevant.

2.1 Do not focus on economic incentives only

The IHSMAG project finds some evidence of economic incentives playing a role in motivating people to take part in smart grid trials and demonstration projects. For instance, the Spanish feedback test pilot (see Riaño Fernandez & Sanchez Perez, 2015) confirms in some way this line of thought, since the fact of not offering economic incentives to the participants is assumed to be an important cause of the failure to meet the participant recruitment objective. Another example is the interviewed participants in the Danish demonstration project *Dynamic Network Tariffs* (a static time-of-use pricing scheme), who emphasise that the possibility of saving money was one of the reasons (among others) why they postponed their consumption to the low-tariff night hours (Friis & Christensen, In press). However, the interviews also indicate that during the demonstration period, the economic incentive to some degree faded into the background, and other reasons became more important, such as more general environmental concerns or the possibility of contributing to an overall (sustainable) transition of the energy system. This was also demonstrated in interviews with smart meter users in the Norwegian Demo Steinkjer (Throndsen & Ryghaug, 2015; Jørgensen 2015). This indicates that it is important for people to find the participation meaningful for them in a broader sense, and not only related to potential economic gains, in order for them to engage actively with smart grid solutions.

Thus, while economic incentives can work as an “eye catcher” in relation to attracting and recruiting consumers for smart grid solutions, it is important to see this as just one among many other possible incentives that may be perceived as meaningful reasons to participate. This is especially important when achievable financial savings are relatively small, as often seems to be the case of time-of-use pricing solutions, and if not, there is a risk of a “backlash” when the participants realize that they save very little money. This was observed in interviews with household participants in the Norwegian demonstration projects *Smart Energi Hvaler* and *Demo Steinkjer*, where disappointment by marginal savings led to disengagement of some consumers and made them less enthusiastic about the smart grid (Jørgensen 2015; Throndsen and Ryghaug 2015). This is in line with other studies concluding that users who do not achieve the expected savings, notwithstanding their behavioural change, might consider the whole experience disappointing and frustrating (Gangale et al. 2013; Hargreaves et al. 2010). Emphasising too strongly possible economic gains can therefore be a double-edged sword, and it is important to strike the right balance.

A similar conclusion is reached in an Australian study of the flexibility of routines in households with children (Nicholls & Strenger, 2015), which recommends that:

> “In particular, understandings of householders’ community responsibility towards energy and electricity assets, the important role of gender in family households, and the dynamics of family routines, are needed to inform energy reforms with this and other household groups.” (p. vii)

We have found related dynamics amongst interviewed users in Norwegian demonstration projects. Often, one person – typically the father/husband/man living in the household – was the one who was originally motivated to participate, partly because of potential economic gains. This, however, often did not translate into significant practice changes, because other household members such as women or children had other and often conflicting motivations, interests and routines. Thus, even in households where a character with similar traits to the Resource Man or Homo Economicus was identified, there were difficulties in implementing the technology in practise as the acts and visions of the resource man was challenged and obstructed by other members of the household pursuing conflicting interests and practices in the context of their everyday life. It was typically the male householders that engaged with the technologies and these processes often alienated significant others in the household. Finally, on the basis of these findings, the paper calls for new design practices in the field of smart energy technology. (Jørgensen, 2015; Jørgensen et al., forthcomming)

That the dominant understanding of simple cause-effect relationship between provision of feedback and rational decision-making does not grasp the dynamics in households’ interaction with smart technologies, is also stressed in a UK field study of households’ feedback on smart energy monitors (Hargreaves et al., 2010), whereby the authors suggest that domestic energy consumption is a social and collective rather than individualised process. The study of Norwegian households come to the same conclusion, stressing the importance of future research focussing more on households and less on the individual energy consumer as the key unit of analysis (Jørgensen et al. forthcoming). This might point to a strategy, which focuses on fostering cooperative and energy-saving household dynamic, and not on educating individuals about their energy consumption.

Other reasons for households’ participation in smart grid solutions could include elements such as the feeling of contributing to a sustainable transition of the energy system; avoiding risks of blackout; saving investments; contribute to energy security in times of crisis; avoiding environmental damage; avoiding expanding the grid capacity and, as a result of this, avoiding new power grid lines (as seen in the debate about the future electricity grid, see Throndsen 2016 for a thorough discussion of the Norwegian case). A higher degree of involvement in these kinds of issues was in fact requested by some of the respondents in the Norwegian study, who also expressed regrets that they were only being allowed to give input to the smart grid development and use as "pure customers". Put differently, they felt somewhat left out of important democratic decision-making processes regarding the development of the grid, and would like to be involved more fundamentally in the development of the Norwegian energy system (Throndsen and Ryghaug 2015).

Along these lines, a typical motivation revealed by our study was the feeling of being "part of a community" or a "collective movement". This was illustrated in the interviews with the participants in the Danish demo projects *Dynamic Network Tariff* and *Test-an-EV* (EV: Electric Vehicle). Here, the interviewed participants often talked about themselves as taking part (along with the other participants) in shaping a new energy system. More specifically, the set-up of especially the *Test-an-EV* project with several information meetings and continuous feedback from the project to the participants seemed to promote a more active involvement of the participants than what one would otherwise expect – and also a high degree of loyalty to the project among many of the interviewees (Friis & Gram-Hanssen, 2013). This indicates that frequent and extensive involvement of participants in smart grid demos can promote a higher level of empowerment, commitment and activity regarding energy issues.

These general observations are very much in line with the previous points made in Chapter 1 about the need to replace today's common understanding of consumers as informed, rational individuals primarily motivated by economic incentives with a broader and multi-facetted understanding of a user: A user, who by no means thinks of her-/himself as only a consumer, as a "barrier", but who rather calls for a greater extent of engagement with the technology and the community as a whole.

2.2 Ensure active (and wholehearted) involvement of users

There are consistent links between gaining results with smart grid technologies in households and involving users actively. This could be done in multiple ways, none of them, of course, exclusive to each other. Users could be invited to participate in the design process, and in shaping the smart grid set-up. Further, once included in projects, for as long as they are ongoing there is a need for a continuous activity aimed at supporting the users' continued engagement. This could include informational activities that provide information about the smart grid technologies and give realistic expectations about their potential. In addition, supporting interaction between users (e.g. sharing experiences with the smart grid solutions) through e.g. physical meetings or via social media could support continued engagement. In this way, the smart grid projects could also support processes of collective learning among the users in relation to new technologies and new practices (see also Christensen, 2014).

These activities should, if possible, be organised at neighbourhood levels, i.e. at the grassroots level, involving the relevance of smart grid technologies in the local context. Keywords would be community, neighbourhood, collaboration, etc. For instance, the study of Norwegian initiatives like the *Demo Steinkjer* and *Smart Energi Hvaler* projects indicates that local "enthusiasts" can play a key role in pushing projects forward, manage the projects, secure that they meet their goals and in making sure that all involved actors are able to formulate their interests, and to work towards the same goal (e.g. health system, building sector etc.). This can for example be entrepreneurially oriented local “champions”, well known in the local community. An example of this was the mayor of Hvaler, who took on a role as a spokesperson for the *Smart Energi Hvaler* project. This project also worked towards engaging users through introducing new concepts and add-ons to the community as time passed. Thus, once the involved users had learned and become familiar with the basics of smart grid and smart home technology, the project introduced new concepts such as the possibility of becoming prosumers through micro-generation of renewable energy or become providers of flexibility through mobilizing the many second homes in the area to balance the grid (see, Skjølsvold and Ryghaug, 2015).

It appears important to facilitate the potential of learning over time, and to make sure that the system continues to provide new and relevant information. This also prevents users from “cooling down”, something that seems to be an active stance the user may adopt, rather than a condition occurring in a passive fashion. This can happen, for instance, in cases where the provision of information from the demo project goes silent for periods or does not take into account and accommodate to the feedback from the users.

Another example of user involvement can be found in the Norwegian *Demo Lyse* project. Here, health care organizations, nurses and the elderly took part in the shaping of the project in order to avoid this user group becoming alienated from what could otherwise be perceived as a too complicated technology. This kind of “local anchoring” of projects can also help ensure that smart grid initiatives for households and at the community level align with specific local challenges and opportunities (see, Skjølsvold and Ryghaug, 2015).

These observations are in line with the findings of other studies. As noted by Verbong et al. (2013: 122): “Approaching users from a centralized top-down perspective increases the likelihood that they will act as barriers.” Typically, top-down approaches experience problems with recruiting consumers and keeping them engaged over longer time, whereas projects with a bottom-up approach seem to experience this as a smaller problem (see also Geelen et al., 2013 on the potential role of community-based energy cooperatives). Thus, while top-down approaches often understand user involvement in terms of a challenges or barriers, the users to a higher degree become important resources to play along with when approached from a bottom-up perspective.

This also challenges the classical “design-and-adopt” approach (often associated with top-down approaches), where the design of technical solutions primarily belongs to the domain of engineers. Rather, the design of smart grid solutions should involve the users already from the beginning of the design process. An early involvement increases the users’ feeling of ownership to the development. Furthermore, as Gangale et al. (2013: 626) point out, a successful engaging of consumers “involves iterative rather than consecutive phases, where continuous observation of consumer response allows adjusting the engagement strategy to the feedback obtained.” These are particularly important principles for user engagement in many smart grid projects where the user has a key role if the project is to meet its goals.

Previous research has shown that smart grid designers tend to believe that the smart grid and its many components are too complex and complicated for ordinary household users to understand (e.g. Schick and Winthereik, 2013; Skjølsvold and Lindkvist, 2015), and that they therefore cannot actively participate in the design and innovation processes. This was also one of the lessons learned from the Spanish feedback pilot in the IHSMAG project. Focused on overcoming technological barriers, the development of the feedback solution to households and the test pilot neglected the real audience.

Much of what we have done in IHSMAG, and what other similar studies suggest, is that it might actually be the other way around. The everyday practices of households are too complex to incorporate in smart grid designs without actually engaging them at an early stage.

A similar experience was found in the Spanish feedback test pilot, where the recruitment of household participants happened primarily by letter. Focusing on specific target groups was not considered pertinent, because the target audience of the test pilot was *any household* living in the Henares Corridor who owned an Android tablet and was interested in taking part. This general and relatively impersonal recruitment method proved to be ineffective. It is likely that concretizing the target audience and creating opportunities to interact with households would have resulted in stronger participation.

An approach, NTNU has been experimenting with as a spin-off from the IHSMAG project, is to conduct smart grid design workshops, where social science students take part in designing solutions that they believe would work in student housing facilities. Our observation from these exercises is that they intuitively identify many problems known in the research literature, while they – at the same time – are able to come up with original ideas and solutions based on knowledge about their own everyday lives and practices.

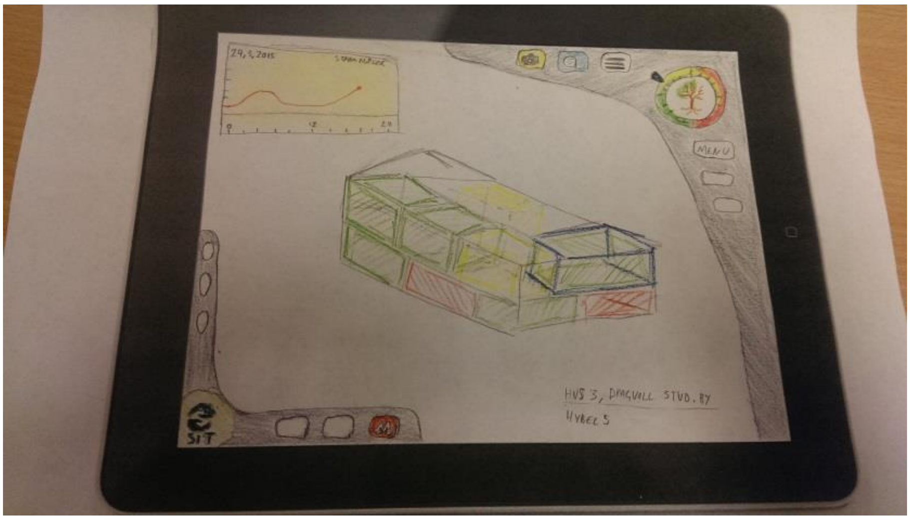

Figure 1. From design workshop for student houses

Another important observation from the IHSMAG project is that users easily detect half-hearted user enrolment efforts (as also indicated earlier). Uncertainty typically characterise early stages of developing and implementing new technologies, and users therefore need few reasons to consolidate scepticism towards utilities or policy makers if not taken seriously. This may ultimately lead to reluctance or scepticism towards smart grid technologies. Scepticism will often be abundant, as also the Spanish test pilot proved, and should be met with realistic expectation building in a transparent setting. Wholehearted involvement of users must be done through non-paternalistic dialogue.

Despite all these pitfalls and the general critique of the traditional approach to designing smart grid solutions for households, the demonstration projects followed in IHSMAG also demonstrate that it is possible to design solutions and approaches, which engage consumers. One example is the Danish *Test-an-EV* and *Dynamic Network Tariff* projects, which experienced a (surprisingly) high level of active involvement on part of the participants. As mentioned earlier, one of the reasons for this seems to be the set-up of the demonstration projects, including several information meetings, frequent feedback to participants about the project, the feeling of being part of an important pilot project and obligations such as daily blogging, continuous documentation of driving patterns, etc.

2.3 Remember the potentially unexpected actors

Since successful design, and ultimately successful use of smart grid solutions, seems to be aided by embedding such solutions in local communities and regions, it is important to keep in mind that the involved group of users or households will not always be the same. In IHSMAG our main focus has been on households. Households, however, might be many things, and they are part of diverse networks with diverse interests. Thus, it is important to look beyond the obvious participants (electricity producers, grid companies and "users") when establishing smart grid solutions.

In Norway, for example, *Demo Lyse* has managed to build a quite successful demonstration project around the notion of welfare technology. The idea here was that smart meters combined with various smart in-home technologies could be useful not only for shifting or reducing electricity consumption, but for making it easier for the elderly and disabled to live in their homes. Through welfare technologies, the aim was to reduce the need for institutionalization or hospitalization, and a new opportunity for commerce emerged at the same time. From the beginning, however, it might not be self-evident that health care organizations had a role to play in smart grid technology development.

Another example with some of the same dynamics could be observed in the Norwegian *Skarpnes Neighbourhood* project. Here, the smart grid demonstration scheme was initiated as a by-product of another "green" technology development, namely the establishment of a new near-zero emission buildings neighbourhood. This was an effort to establish new types of households, which would reduce the overall electricity consumption. This approach did not originally grow out of a smart grid-related idea. However, it soon became clear that all the new, automated technologies that were to be included in this neighbourhood project eventually could pose a challenge for the electricity grid of the area. Thus, it was actually the building contractor who was the catalyst behind the effort from the start (see, Skjølsvold and Ryghaug, 2015).

Electricity grids constitute a vital societal infrastructure, in principle used by all. Thus, it is important to look at the potential users in an area where a pilot is planned and take into account their individual needs. In *Demo Lyse*, an innovation workshop with nurses and other representatives in the healthcare sector led to a new approach towards designing technology also for households. It is impossible to predict similar synergetic relationships in other settings, but we want to emphasize the generative potential in searching for them and exploring them.

In sum, the IHSMAG project shows the need to make the smart grid distributed and multiple by opening up for a democratic approach including a wide range of different stakeholders, interests and aims in policy and decision-making as well as in specific design and innovation projects.

2.4 Look for positive synergies between smart grid solutions

Trial and demonstration projects often aim to involve households in relation to one specific type of solution (e.g. energy feedback to consumers, energy efficiency or time shifting of electricity consumption). However, experience from the study of Danish households participating in both the trials *Dynamic Network Tariff* and *Test-an-EV* indicates that the combination of solutions (in this case time-of-use pricing and electric vehicles) might imply potential synergies that can strengthen the effectiveness of otherwise separate solutions. In the Danish case, the initial focus was primarily on encouraging demo participants to charge their EV in hours with low electricity price (non-peak hours). Interestingly, our study showed a spill-over effect in relation to time shifting within other areas of consumption (in particular laundering and dishwashing). (Friis and Christensen, In press)

The design of smart grid solutions should take into account and encourage these kinds of synergies and positive spill over effects.

2.5 Be aware of possible negative, unintended effects

It is well known within the literature on energy saving that higher energy efficiency is often followed by increases in consumption, which partly offsets the achieved (technical) savings. This kind of unintended effect is known as the rebound effect and has been demonstrated in relation to many consumption areas, such as driving and home-efficiency improvements (see e.g. Greening et al., 2000 and Sorrell, 2009)

Similar examples of unintended, negative effects (rebound effects) might be expected in relation to the implementation of smart grid solutions. One example from the Danish IHSMAG study is how the “branding” of electric vehicles (EVs) as an energy efficient and environmentally friendly alternative to combustion engine cars made some participants feel more relaxed of using the car more often as it would not “make harm to the environment” and because of the cheaper price of electricity compared to petrol. In particular, some started to use the car more often for shorter trips instead of cycling and walking (even though some of the increase in the driving frequency presumably also relates to the participants’ eagerness to test the new EV technology).

Additionally, and even more crucial, some of the participants experienced that having two cars in the household (their ordinary car and the EV) was convenient in relation to their efforts to juggle the obligations and duties of their everyday life. They found the idea of acquiring an extra car (after the end of the test pilot) attractive. Future designs and promotions of EVs should take this kind of potential rebound effects into account.

In the Norwegian study, we have identified two main unintended consequences of participating in smart grid demonstration projects. The first has been noted already, and was found amongst users who thought the promotion of the smart grid solutions oversold the rhetoric of “savings” and monetary rewards. When such rewards were not realized, users reported that what they had learned from e.g. in-home display information was that it was incredibly cheap to consume electricity, and consequently they did no longer see any reasons for changing to less energy intensive routines.

A related example could be observed amongst some users in *Demo Steinkjer*. This group had installed a smart meter, but in order to access the feedback data from this meter they had to log in to a new online portal. Thus, they explained that the main difference between their old and “new electricity consumption behaviour” was that they no longer had to read the electricity meters themselves and that they no longer received the electricity bill in the mail. The bills were now automatically sent to their bank, the payment automatically drawn from their account, thus the smart grid had forged them from minimal confrontation with their electricity consumption every quarter of the year in the past to no engagement at all. This actually made them less preoccupied with their energy use.

An example of a potential “systemic” rebound effects relates to peak shaving: The electricity sector shows increasing interest in time shifting the electricity consumption of households – often by use of time-of-use pricing and economic incentives. As a result (and if the initiatives are successful), this will increase households’ electricity consumption in some periods (particularly in the night) and reducing it at other times (peak hours). However, emphasising the possibility for saving money when consuming electricity at times when electricity is “cheap” might indirectly motivate households to increase their overall electricity consumption, as they would regard new (increased) electricity consumption as inexpensive as long as this happens at low-peak hours.

Something similar to this was observed in the Spanish feedback test pilot in relation to the participants’ response to qualitative consumption recommendations. More than 67% of the recommendations encouraging increase in consumption (in hours with high level of electricity production and low level of consumption) were followed, while only 31% of the recommendations on reducing consumption were followed.

2.6 Data needs to be collected and made accessible to end-users without compromising data privacy

The roll-out of Advanced Metering Infrastructures (smart meters) opens up for new opportunities of utilising the detailed data about households’ electricity consumption patterns for different purposes, including detailed feedback. In principle, data could also be shared with third parties (based on the customers informed consent), who could offer various kinds of services such as tailored energy saving advice based on the historical metering data. Also, the energy supplier could offer similar services to customers.

However, important questions regarding privacy and data security follow with the new opportunities for detailed monitoring and storing of households’ consumption data. Thus, the question of data protection, privacy and data ownership has been identified as one of the main issues and challenges related to the smart grid development (see e.g. Gupta, 2012; Heffner, 2011). Therefore, allowing users (or third parties) to access consumption data stored by the smart grid system implies the development of a safe and reliable protocol to minimize data leaks or misuse.

First of all, secure authentication must be implemented. Before accessing the smart grid system, the users must identify themselves. The most common methods to implement authentication are: 1) Entering an assigned username and password or 2) Providing IP address or MAC filtering (in this case, only the defined IP addresses or MACs can access the Smart Grid System). An additional cybersecurity solution is to encrypt the data.

In the Spanish feedback test pilot, not only username and password login was implemented, but also the server containing all participant consumption had encrypted communication, using a trusted certificate from a Certification Authority (CA). In this way, privacy was guaranteed for all involved parties (utilities, households and distributors).

Another noteworthy issue related to data collection observed in the Spanish feedback test pilot in the Henares Corridor was the consequences of making the Home Display App available through the Google app store. Here, people that did not adhere to the test pilot were able to download the application, and, consequently, to send a request to the dedicated server. They were not allowed to access any information as long as they did not have a registered username or password, but their requests of trying to access the system caused traffic data, which reduced the communication efficiency.

At the same time, specific and proprietary web services must be developed for every utility company and for every system (data concentrator or dispatch) based on a shared set of web standards. One of the problems for smart grid deployment is facing the enormously competitive electricity market. Thus, forcing utilities to adopt the same tool in order to allow end-users to communicate with their servers may be doomed to fail. But proposing a general solution, based on standards such as web service technologies, where each utility develops its proprietary tool, might be realistic.
The Spanish test pilot followed this approach, and it proved to be effective in overcoming most of technological barriers related to communication.

2.7 Make smart grid solutions easy to understand and use

A general recommendation is that smart grid solutions should be made easy to understand and use by the households.

Users have varying levels of competences and knowledge about electricity-related parameters. Therefore, the provided data should be easily understandable. For example, information should be presented in graphs, which are easier to understand than numbers. In order to follow a standard on how to show consumption data, kWh seems to be central. However, it is advisable to add examples in order to clarify “what a kWh is”. For example, besides the consumption charts with kWh, tips such as "A dishwasher of class performance A consumes about 1 Kwh per wash cycle" or "A fridge of class performance A consumes daily about 1 Kwh" could be included in the user interface. In other words, it is recommended to visualise data and make comparisons to things people can relate to or that they have daily experiences with.

An example from the IHSMAG project, which shows the importance of simple solutions, was the Norwegian *Demo Lyse* project. Here, the participating households had a number of available technologies. They could use tablets or displays, both to receive information and to control aspects of their consumption. They could also log in to web portals and they could use their smart phones. However, in addition to these “smart” solutions, many users had installed hard-wired scenario switches, pre-programmed with settings for the home such as “day”, “night”, “vacation”, “movie” etc. In terms of popularity and frequency of use, these simple, analogous looking type of switches were by far the most popular amongst users.

Figure 2. Smart grid solutions can be very simple, but still popular (the labels state: Home/Away, Normal/Reduced, TV set on/TV set off).

In relation to load shifting by use of time-of-use pricing, the findings from the Danish demo project *Dynamic Network Tariffs* show that schemes based on fixed price intervals (also called *static time-of-use pricing*) are easier to understand by the households compared to schemes based on prices that change continuously from hour to hour and day to day (also called *real-time pricing*). Static time-of-use pricing makes it easier for the household members to develop new routines and shift electricity consumption on a permanent basis. The Danish study indicates that the time shifting in electricity consumption was not so much depending on the actual cost savings (which were in general small), but rather depending on the fact that static time-of-use pricing conveyed a general and comprehensible information about at which hours it would be most suitable for the system and for the participants' personal economy to consume electricity. Similar results have been found in other trials with static time-of-use pricing. For instance, Darby & McKenna (2012) conclude, on the basis of the experiences from an Irish trial, that "the main factor affecting customer response was the existence of time-varying prices, rather than the actual figures involved" (ibid.: 766). Thus, a general recommendation is that fixed price intervals should be preferred over real-time pricing for households – at least for solutions that aim at the active involvement of households in shifting their daily practices (like dishwashing and washing clothes). However, this may not apply to situations with automated or remotely controlled systems.

This has also implications for what kind of system challenges that time shifting of household consumption might contribute to: It is more likely that households can contribute to general shifts in electricity consumption (e.g. peak-shaving) rather than the day-to-day and even hour-to-hour challenge of balancing power consumption with intermittent renewable electricity generation. Thus, electricity systems based on a high share of "uncontrollable" power production (like wind power) might find solutions targeting an active involvement of households less feasible compared to electricity systems primarily based on more controllable sources (like hydropower).

Simplicity can sometimes (but not always) relate to automation of specific actions or processes through, e.g., centralized, remote control. An example of this is from the Danish *Dynamic Network Tariff* trial, were the interviewed participants expressed a high willingness to let the mobility operator control the charging of their EVs during the night, which would guarantee them the cheapest electricity price. The households' acceptance of central load management was not only about money saving, but also a question about convenience and comfort. The assumption among the participants was that with central load management, they would avoid the trouble with remembering to plug-in the cable and start recharging before going to sleep – although most participants did succeed in doing this on a regular basis, even without the central control.

2.8 Time shifting energy consumption – take into account the temporal rhythms and the spatial qualities of the home

Within the smart grid development, there is much focus on demand-side management and time shifting. The Danish study shows that households are able to time shift some of their everyday consumption, but this most likely happens in relation to practices that involves *semi-automation* of daily practices. More specifically, the *Dynamic Network Tariff* trial in particular showed time shifting of dishwashing and laundering (in addition to charging EVs). Our findings suggest that this was mainly due to the fact that these practices involve semi-automation, i.e. some of the activities related to, e.g., dishwashing are delegated to the dishwasher, which can run its cycle independently of the household members' direct intervention. This makes it possible to time shift these cycles to night time, for instance.

However, the study also shows that time shifting has implications for the daily rhythms and temporality of the household members and can be a source of inconvenience. This was in particular the case in relation to time shifting laundering to the night hours, which resulted in a new activity (habit) of hanging clothes to dry in the morning hours. As this activity coincides with the often rather busy morning hours in families, this is experienced by many as stressful and inconvenient. Also because handling the laundry in the morning implies that one parent needs to be away from the common areas of the home, and in this way cannot take part in what for many was considered meaningful and much appreciated family time around breakfast.

No matter how trivial or "mundane" this example might seem, it points to the important observation that solutions aimed at influencing household members to shift the timing of their daily practices need to recognise the temporal complexity of the household members' everyday life and the meaningful social interaction within the home. Thus, to ensure designs that work in practice, it is crucial to develop time shifting solutions and designs with a keen eye to this complexity and through active involvement of the prospect users through the entire design.

Our study also shows that not only the temporality of practices and the everyday life of households play an important role, but also the materiality of the home and its spatial layout. Thus, noise from machines running during the night (e.g. dishwashers and washing machines) can interfere with other activities of the household members (like sleeping if the machines are placed close to bedrooms). In this way, noise can effectively hinder the time shifting of activities such as dishwashing and laundering. This can be a problem within the household, but also between households in apartment buildings where neighbours live close to each other. These aspects need to be taken into consideration when designing solutions for time shifting. Thus, when designing “smart grid ready” appliances, so called trivial aspects such as creating low noise and vibration technologies can essentially be equally important design criteria for the smart grid ready appliances than built-in features for remote control etc.

Finally, in relation to time shifting, it has been pointed out at several occasions that insurance policies covering fire and household contents do not cover fires caused by white goods like dishwashers, washing machines and tumble dryers running while people are not at home. In addition, experts and consumers’ organisations recommend people not to run their white goods while they are not at home or at sleep due to risks of water damage or fires (see, e.g., Forbrugerrådet Tænk, 2016). This indicates that there might be important challenges related to insurance policies and potential health risks related to time shifting. It seems as these aspects deserve further exploration.

2.9 Promote energy saving through comparisons with others

Providing households with (visual) comparisons of the size of their own electricity consumption with the size of the consumption of their neighbours or households similar to themselves might be a way of increasing general awareness about own electricity consumption and motivate to save electricity. Obviously, data security and privacy issues have to be considered when taking such measures. However, grouping users on basis of certain common characteristics and providing the average data of the group (who shares these characteristics) could be a way of avoiding privacy matters. In this way, each household could compare their own consumption with others’ consumption without disclosing individual consumption data. Possible common characteristics include geographical area (neighbourhood, city and country), socio-demographic characteristics (age, gender, marital status and number of residents) and type of electricity contract. However, this has to be done in a thoughtful way. The *Demo Steinkjer* respondents were moderately sceptical about this type of comparison, as they feared that they would be compared with not really comparable household neighbours (for instance differing a lot regarding number of household members, size of floor space etc.). The parameters making the basis of such comparisons should therefore be transparent to the users or they may be dismissed by end users, in turn rendering these kinds of initiatives ineffective.

Previous demonstration projects have shown that comparison with others do have a relative high influence on customers’ interest in saving energy. An often-mentioned example is the American OPOWER project in which electricity customers were mailed a “Home Energy Report” that included neighbour comparisons as well as energy conservation tips. The study indicated an average reduction in electricity consumption of 2% (compared to a control group) and showed highest reduction rates for customers in the highest consumption decile (Allcott, 2011). More generally, studies indicate that normative social influence (like comparing one’s own performance with others) and social norms (“what other people do” – or are believed to do) are having a greater impact on people’s energy conservation activities compared to other kinds of initiatives such as general information about environmental negative effects of electricity consumption (Nolan et al., 2008). However, the real (long-term) savings and effects from these kinds of studies are often difficult to detect.

2.10 Feedback data should be real-time

Feedback information to households should ideally be real-time. One example could be real time notifications if a threshold consumption level defined by a user (daily or monthly) is exceeded. This could be an incentive for households to save energy. The threshold could be based on the household's historical electricity consumption (i.e. their "normal consumption"), a self-defined maximum level of consumption or the average consumption of similar households (cf. Section 2.8). This kind of solutions requires technical development on the electricity utility side in order to be able to provide this kind of service to the customers.

Another example could be real-time information about the environmental impact of energy consumption (based on data about the actual mix of electricity generation in the system). The information should be based on homogeneous, realistic and standard criteria.

For feedback solutions more generally, other studies also indicate the importance of real-time feedback. For example, Hargreaves et al. (2013) found that real-time feedback is important for householders as this makes it possible for them to monitor and follow what impact their changes of daily habits have on the energy consumption. In our project we found that real-time feedback data supports active "experimentation" and learning processes in relation to energy saving (Christensen, 2014: Jørgensen 2015).

2.11 Feedback data available on a non-aggregated level

Efforts should be made in developing solutions that make it possible to provide households with consumption data on a non-aggregated level (i.e. an appliance-specific breakdown of the households' electricity consumption). Otherwise, the users will only be informed about their aggregated consumption, which gives no clear idea of when and where electricity has been consumed. Like real-time feedback, this would support active experimentation and learning processes regarding the household's use of electricity and possible ways of saving electricity. Previous studies have reached similar conclusions, e.g. Fischer (2008) and Hargreaves (2013).

2.12 Smart home appliances

Related to the previous section, the technology in homes seems to be crucial in relation to providing non-aggregated consumption data. The development of mini-meters or smart plugs, which provides data on the electricity consumption of specific devices, is a key to increase awareness of users about their electrical consumption.

In relation to this, smart home appliances would be the second step. Once the non-aggregated consumption of certain devices is available, the possibility of choosing other performance cycles to change consumption pattern is a powerful tool. Selecting eco programmes on washing machines or dishwashers, being offered to reduce the brightness of television or computer, or even being able to pre-program a reduction of the set-point temperature of the fridge when it is not being used are more specific examples of potential uses of smart appliance.

In the long term, automated household appliances should be prepared not only for monitoring the electricity consumption of the appliances or control them manually, but also for controlling them remotely. In this way, the home appliances would be prepared for demand-side management (like time shifting of electricity consumption) on a short-term basis. This could be a supplement to other solutions that more directly and actively involve consumers in time shifting their electricity consumption.

3. Recommendations for policy makers

This section focuses on recommendations and key lessons for policy makers and people involved in the overall designing of smart grid development processes (e.g. planners and system designers).

The guiding questions for identifying and developing the following recommendations have been:

- What kinds of actors play key roles? And how?
- How to support a comprehensive and integrated approach through policy-making?
- What are the more general policy-making implications of the results of the IHSMAG project?
- What kind of existing approaches should be promoted? What kind of approaches should be avoided?
- What are the key obstacles (technical, political, organizational)?

3.1 Flexibility and openness in policy important

How can we ensure a transition towards a “smarter” energy system? One option is of course to have faith in technology development and future markets, and to allow the technological development to unfold without political interference. The drawbacks of this approach are that it might take a very long time, and that much opportunity for controlling the development (or lack thereof) is lost. On the other hand, there might of course be much creative potential in a pure market driven approach with entrepreneurs pursuing the options they find viable. In IHSMAG, we have studied smart grid policy processes in Norway (see Skjølsvold, 2014). Here, the government has decided on a mandatory implementation of smart meters through regulation. In one sense, this has proven to be an effective strategy, because mandatory rules enforce some sort of transition. Additionally, our study of the Norwegian regulatory practise related to the roll-out of smart meters has led to two concrete recommendations, which we believe can facilitate learning on behalf of involved actors in smart grid roll-out processes.

Our first recommendation is that there should be *ample time* between the regulation is announced and its enforcement. In the Norwegian case, the authorities’ intention to implement the technology through grid management regulations became known to the industry actors already in 2008 after some years of debating the issue already. Thus, political imaginaries of “what” the smart grid could become in the future was in the making, and network operators were forced to involve themselves in this process by the roll-out being made mandatory by regulation. As the final wording of the regulation was not ready before 2013, this has given Norwegian stakeholders more than ten years to prepare for this massive infrastructure upgrade.

Initially, this time was spent by grid operators to collaborate on establishing a shared interpretation of the regulation, which was important for the regulator as well, because the goal of the smart grid is to create solutions that harmonise across regions and borders, as well as with potential market solutions in the future. Network owners on their end were driven by the need to make technology choices which would “fit” into the smart grid in the future, something which caused involvement in smart meter development to be a virtue of necessity for many of them (Throndsen, 2016). The study of the Norwegian demonstration projects shows that this basis, once established, enabled different actors to “use” the mandatory smart meter roll-out to achieve quite different goals, more specific to local needs and circumstances, and to experiment with quite different set-ups, both in terms of organization, choice of technology, user focus, and collaboration with other relevant actors (Skjølsvold and Ryghaug, 2015). Such goals and ideas were not necessarily explicitly formulated before the authorities announced that they would make the roll-out mandatory. This suggests that an artefact such as a smart meter holds great potential as an entity with generative capacity in terms of paving the way for collaborative efforts, as was seen in the case of Norwegian network owners organising themselves in a middle-out fashion in order to meet the regulatory demands and establish a shared understanding, again constituting a common risk mitigation exercise. Given less time to establish this common basis and understanding, it is uncertain whether the local-specific heterogeneity observed among different demo projects would have been achieved.

Further, the monopolized Norwegian electricity grid sector was highly ambiguous towards the roll-out at an early stage. Providing time for trial and error might also be a way to engage and establish enthusiasm amongst core actors in the electricity sector.

Embedding a broad technological scheme such as the smart grid in a local setting takes time. It requires that new business models are designed, that new inter-sectorial networks are established and maintained over time, that new social relations thrive, and that there are trust among the relevant stakeholders. This is also a challenge that involves bridging some crucial gaps between scholarly approaches such as power engineering, ICT engineering and business/economics and various social sciences. Thus, we advise that mandatory roll-outs should be designed with ample time for learning in order to coming to terms with all these issues *before* the full scale roll-out is conducted.

In addition, it is important to make regulation that allows for, and perhaps stimulates, *flexible solutions*. As we have already suggested, different localities, regions and countries consist of very different actor constellations and interest structures. This means that there are many different potential ways of mobilizing and designing smart meters and related technology, by which implementers can create value for themselves, beyond the obvious possibilities of in-home displays and automated control.

Our second recommendation is that it could strengthen the potential for innovation if the regulation of technology is relatively *open-ended*, with quite open standards so that it can be used for multiple purposes and be exploited by third parties. This would allow different actors to build new solutions “on top of” the technology. Examples of this were identified in both the *Demo Hvaler* and the *Demo Lyse* case studies in Norway. In Demo Lyse, for example, radically different solutions and set-ups were established for student housing facilities and for the elderly.

Building on Elinor Ostroms work on systems of common pool resource management, Maarten Wolsink (2012) suggests that smart grids and distributed energy systems share many of the traits of these systems. Decades of research on polycentric commons (such as grazing lands, fisheries, water sources etc.) – where the outcomes are shaped by the collective action of many stakeholders – suggests that top-down regulation without an eye towards local institutions, customs and practices usually fails. Instead, systems that are allowed to operate based on some sort of localized logic have a better chance. Wolsink (2012) compares the current smart grid regulation development to the early development of renewable energy, one or two decades ago. Then, social issues were largely neglected, and thus the development of renewables was hampered. In Wolsink's eyes, we do the same mistake today if local social issues are not brought to the forefront of policy development.

Other researchers also bring the latter recommendation forward. For instance, Friedrichsen et al. (2014) advocate for more flexibility in the future regulation of smart grids and notes that "the increasing number of and heterogeneity of stakeholders make 'one-size-fits-all' regulation simply less suitable, whilst regulation needs to take account of various interests" (ibid.: 261). The authors also conclude that due to the decentralisation of the electricity system, the entering of new actors and existing actors getting new roles, more individualised approaches and more coordination of the stakeholders across the system are needed.

3.2 Use intermediaries to engage the public

Both in a physical and metaphorical sense, there is often a long distance between authorities and households in which the technologies are brought to use. The same can be said about the distance between the authorities and electricity sector companies. Thus, regulators should strive to enrol intermediary organizations or actors who can engage in active dialogue with implicated actors at different scales. In Norway, for instance, the non-profit industry organization *Energy Norway*, who represents about 270 companies involved in the production, distribution and trading of electricity, has been crucial for establishing arenas where actors from different industries and the policy and regulation sphere can exchange experiences and opinions about common problems and solutions. It has also served as an arena for negotiating the outcome of the smart grid efforts, made robust by broad support by the actors. This was necessary because of the infrastructural characteristic of the smart meter, and the need for it to be more or less uniform across the country, and indeed, across borders.

The next step in developing the smart grid is creating viable and marketable solutions for end users. In Norway, this has been left entirely up to the market as the smart meter is installed by grid companies. Thus, the market has been given the task of further exploiting the potential made possible by the capabilities of the smart meter. In comparing the situation of the mandatory roll-out with the burgeoning market place of smart grid solutions, it is plausible that some sort of venue, similar to the one set up by *Energy Norway*, could prove conducive. If so, the need for uniform solutions by the network is replaced by the need for *relevant* solutions by the users; meetings between actual users and designers can occur and may cater for solutions, which resonate better with the needs of households, neighbourhoods and communities.

Some examples of the use of intermediaries can be seen through the four Norwegian smart grid demonstration projects studied in IHSMAG. In one sense, these projects are clear examples of direct efforts of public engagement. For most participants in such projects, they represent the first encounter with smart grid technology. As with all first encounters, this is not trivial. If this encounter creates aversion or negativity due to perceived lacks or neglects in the ambitions of designers and technology, the route towards achieving user relevant outcomes might become much longer. Furthermore, when participating in demonstration projects, households and citizens are turned into opinion leaders who might also serve as intermediaries, distributing knowledge, attitudes etc. to their respective social networks.

The Norwegian study illustrates how important demonstration projects are as both active intermediaries and incubators for public engagement, and regardless of whether they manage this task successfully as well as unsuccessfully. Several of the respondents in *Demo Steinkjer*, for example, stressed that the sudden lack of engagement and dialogue in the later phase of the project constituted a vacuum, which created frustration with and speculation around both the technology and the project in general. At first they were introduced as a “very important” part of the smart grid, but a year later they felt they were largely forgotten, constituted by a lack in follow-up on part of the demo. On the other hand, *Demo Hvaler* illustrates that it is possible to use demonstration projects to mobilize a very positive political dialogue between local authorities, industry and market actors, and citizens regarding issues such as sustainability, renewable energy and the smart, relevant uses of smart grid technologies.

With these dynamics in mind, regulators should consider stimulating, funding and promoting such demonstration projects, not only as sites of technology verification, but also as sites of public engagement and genuine dialogue. This, we believe, would also create very stimulating feedback loops, which would be of great value also for those designing specific smart grid solutions.

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